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EROSION INTENSITY ASSESSMENT USING EROSION POTENTIAL METHOD AND GEOGRAPHIC INFORMATION SYSTEMS: A CASE STUDY OF BEOČIN MUNICIPALITY, SERBIA

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ABSTRACT: *Soil erosion is considered as one of the most common forms of degradation, and as such affects the environment. Nowadays there are various methods to assess the loss of soil due to erosion and represent an alternative means by which it is possible to estimate the amount of soil loss in the given area. In this paper Erosion Potential Method (EPM) is used by applying GIS in the territory of the municipality Beocin. The preliminary parameters in the form of raster maps have been previously prepared: the digital elevation model, the pedological and geological map, the Corine Land Cover, as well as the results of previous pedological studies in order to determine the soil erodibility factor. In the investigated area processes from first to the fifth category of erosion were observed. The degree of threat to erosion processes is in proportion to the extent and type of activity in the investigated area, which was expected due to the high inclination of the terrain and unstable geological substrate. The Erosion Potential Method proved to be suitable for defining erosion processes in the investigated area, although the input parameters were insufficient.*

Keywords: *GIS, soil erosion, Erosion Potential Method, natural resources, erosion map*

APSTRAKT: *Erozija je jedan od najčešćih oblika degradacije zemljišta. U ovom radu korišćen je Metod potencijala erozije primenom GIS-a na teritoriji opštine Beočin. Prethodno su pripremljeni ulazni parametri u vidu rasterskih mapa: digitalni model visina, pedološka i geološka karta, Corine Land Cover, kao i rezultati ranijih pedoloških istraživanja u cilju određivanja faktora erodibilnosti zemljišta. Nakon izrade same karte erozije urađena je klasifikacija procesa od prve do pete kategorije razornosti. Stepen ugroženosti erozionim procesima je u srazmeri sa obimom i vrstom aktivnosti na istraživanom području, što je bilo očekivano usled velikog nagiba terena i nestabilne geološke podloge. Preovlađuje površinska erozija, dubinska erozija se mestimično javlja u vidu vododerina, brazdi, jaruga na padinama i u samim vodotocima. Metod potencijala erozije se pokazao kao pogodan za definisanje erozionih procesa na istraživanom području, iako su ulazni parametri bili nedovoljni.*

Ključne reči: *GIS, erozija zemljišta, Metod potencijala erozije,prirodni resursi, Karta erozije*

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INTRODUCTION

Erosion is considered to be a natural phenomenon that leads to the displacement of parts of soil and rock due to water, wind, ice and gravity. The degree of erosion is mainly determined by physical factors, for example, soil characteristics, the formation of rocks, topography and the amount of soil material that is available for transfer, which usually is proportional to the erosion ability of soil and land use (Amiri, 2010).

The assessment of soil erosion and sediment transport in hydrological catchments is imperative, in different temporal and spatial scales, in order to protect and preserve soil as long as technical constructions such as irrigation dams, hydroelectric projects and flood attenuation structures (Panagoulia and Dimou, 2005). This need has led to the development of different simulation models, and thus empirical models are widely applied, especially in countries where the availability of input data is often scarce and the validity ambiguous, because of their simplicity and ease of use, having fewer input data and computations demands than the comprehensive ones. Moreover, numerous cartographicmethods are available today to estimate the risk ofthe soil erosion by water (Husnjak et al.,2000).

One of the most widely accepted and applied empirical model is the Erosion Potential Model (EPM), also known as the Gavrilovic method. The method takes into consideration surface geology and soil properties, topographic features, land use type and distribution and the catchment's degree of erosion. It has been widely implemented throughout the Balkans as well as in other countries, providing reliable results on qualifying soil erosion severity, as well as implementing torrent regulation and other erosion control measures (Gavrilovic, 1970b)

This paper will determine the interaction between the dominant physical-geographic and anthropogenic factors that influenced the intensity of erosive processes, on the example of the territory of Beočin municipality using the EPM. The model will be implemented in a GIS-based environment, with each factor being described by the form of a digital map. The digital maps derive from the digital elevation model (DEM) as long as geological, pedological and land-use maps, taking also into account data field measurements and information available in the literature. The digital layers are then overlaid in order to calculate potential soil erosion (Raghunath, 2002).

RESEARCH AREA AND METHODS

Study Area

The investigated area is located in northern Serbia, about 85 km northwest of Belgrade and 10 km south of Novi Sad. Compared to the predominantly plain areas, Fruška Gora is a distinct mountain region. The direction of this mountain is east-west, in the length of 80 km, with a maximum width of 15 km. The area covers the municipality of Beočin, which borders the municipalities of Novi Sad, Backa Palanka, Backi Petrovac, Sremska Mitrovica and Irig (Figure 1).

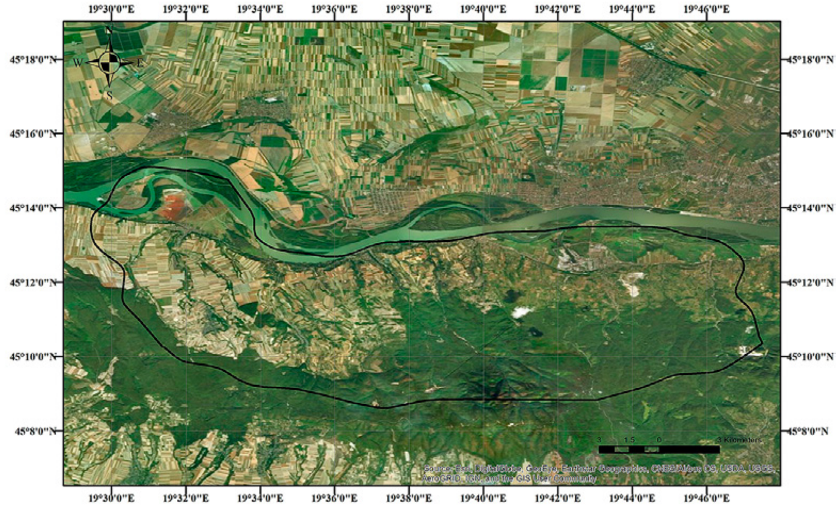

Figure 1. Topografic map of area

The hydrographic network of Fruška Gora is very dense and relatively well distributed. Considering that the entire area is on the northern slopes of Fruška Gora, the municipality is distinguished by a developed hydrographic network. The following streams are present in the municipality of Beočin: Lišvarski, Čedomir, Sviloški, Tekeniš, Čitluk,

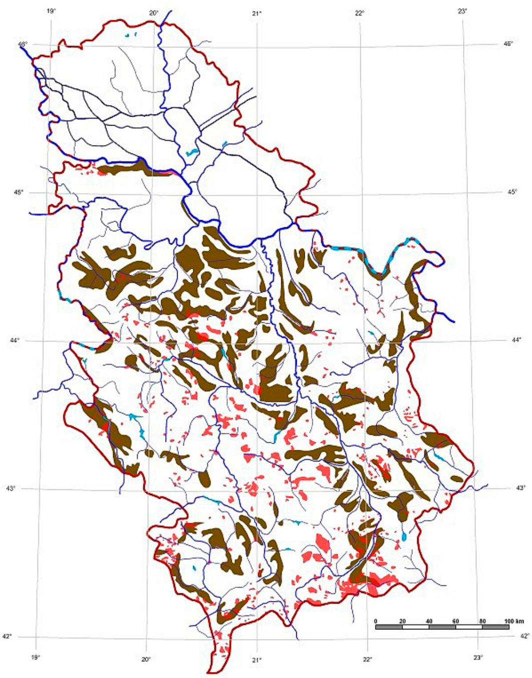

Figure 2. Map of unstable slopes and areas with high erosion potential (according to the Environmental Protection Agency)

Potoranj, Čerevićki, Šakotinac, Kozarski, Časorski, Dumbovački and Rakovački (Javno preduzeće NP Fruška gora, 2011).

According to the results of theEnvironmental Protection Agency (www.sepa.gov.rs), the territory of Beočin municipality is in the area of severe erosion (Figure 2). This is why this area was chosen to implement EPM model on it.

Topographic data

The topographic data of the area under study were obtained through the digitization of maps 1:25000 made by Military Geographical Institute of Serbia using ArcMap 10.3.1. Using the same program, various characteristics were estimated for each hypsometric curve set, such as DEM, slope, elevation, and so on. Using these different quantizations in ArcMap, we were able to estimate the variation in slopes (mean–max) and elevation (mean–max) for the selected basin. Geology and pedology were analysed based on maps from The Provincial Secretariat for Energy, Construction and Transport, and is shown in Figure 3 and Figure 4. For vegetation and land cover, the Corine Land Cover database (CLC 2016) was used (see Figure 5).

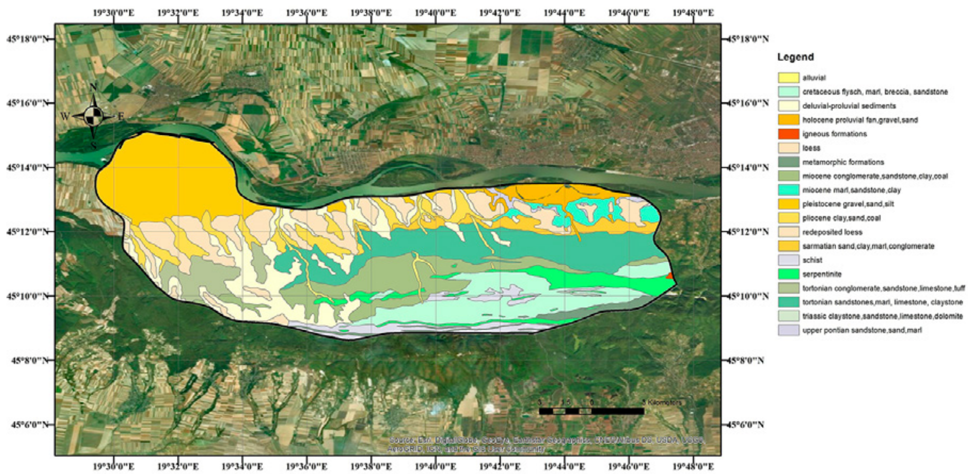

Figure 3. Map of geological formations

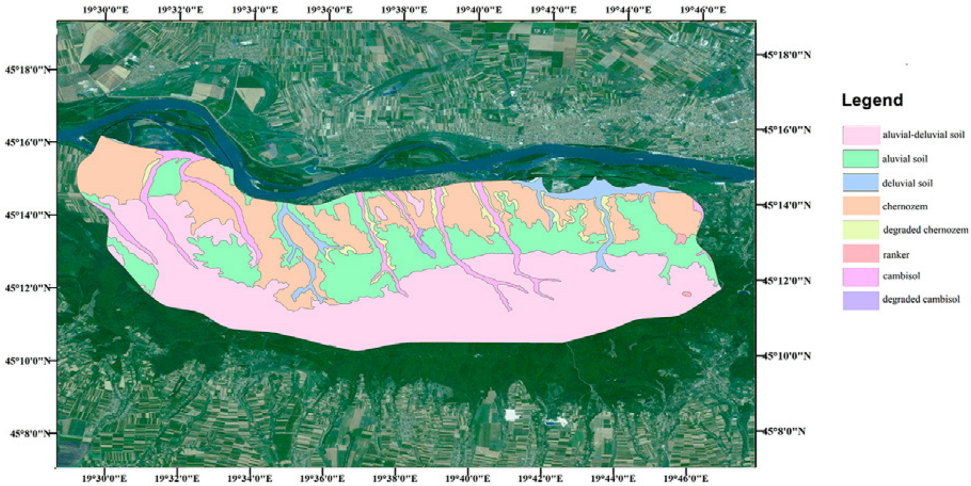

Figure 4. Map of soil cover

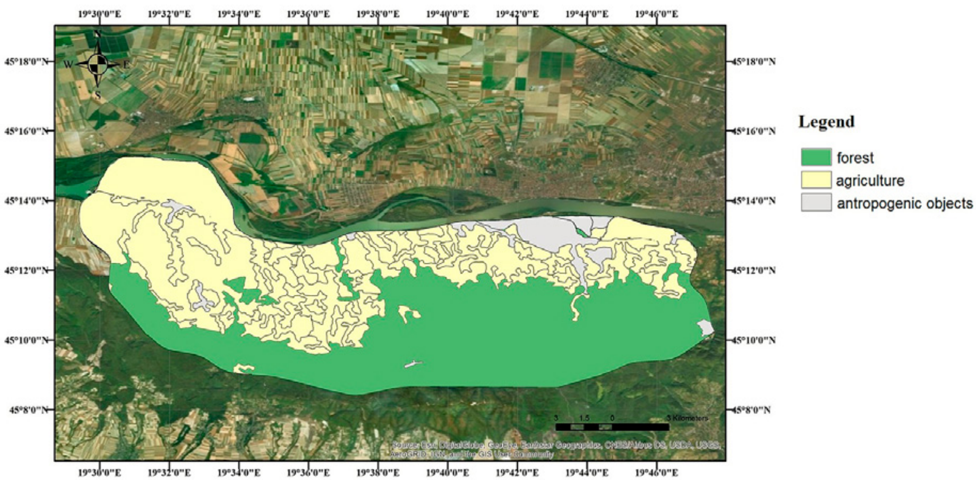

Figure 5. Corine Land Cover

The Erosion Potential Model (EPM)

The method is based on the analytical processing of data on factors affecting erosion. The erosion spatial phenomenon appears on the map according to the classification based on the analytically calculated erosion coefficient (Z), which does not depend on climate, but on soil characteristics, vegetation cover, relief and visible representation of erosion. The coefficient of erosion (Z) is obtained from the following Eq. (1) (Gavrilovic, 1970a). The Figure 6 shows the flowchart of the model.

$$Z=X \cdot Y \cdot (\varphi+\sqrt{Isr}) \quad (1)$$

where X is the soil protection coefficient, Y is the soil erodibility coefficient, φ is the erosion and stream network development coefficient, Isr is the average slope of the watershed.

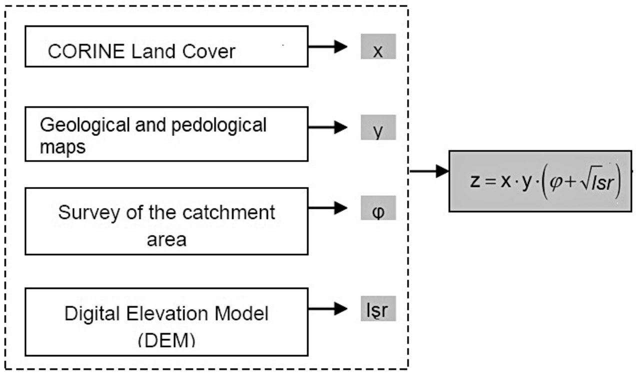

Figure 6. EPM flowchart

Soil protection coefficient (X) (depends on land use and vegetation cover) expresses numerically the protection of an area against precipitation and erosion. Its values are tabulated and, as shown in Table 1, ranging from 0.05 (lower limit of the "Mixed and dense forest" class) to 1.0 (upper limit of the "Areas without vegetal cover" class). Soil erodibility coefficient (Y) (depends on geology and pedology) can be expressed as the inverse value of the resistance of soil to erosion due to the erosive force of precipitation. Its values are tabulated, ranging from 0.20 (lower limit of the "Hard rock, erosion resistant" class) to 2.0 (upper limit of the "Fine sediments and soils without erosion resistance" class). Coefficient φ stands for the degree of expressed erosion processes (visibly characterized) in the catchment. Its values are tabulated, ranging from 0.10 (lower limit of the "Limited erosion on watershed" class) to 1.0 (upper limit of the "Whole watershed affected by erosion" class) (Gavrilović, 1988).

The basis of preparation was CORINE Land Cover database, which is used for the creation of the polygons provides a good definition of the areas of the same use of land. Obtained polygons, by analysis of thematic geological and soil surface, are given the coefficients of the soil erosion resistance (Y).

By the use of a digital elevation model (DEM), a thematic layer of slopes is created that overlaps with the manner of the land use polygons, which is assigned the coefficient of X and Y (Figure 6), and using the zonal statistics, each existing polygon is given the average slope Isr. The coefficient type of erosion Φ, which indicates to a state of erosion processes, is determined by taking into account all the parameters above (Gavrilovic, 1988).

Table 1. EPM coefficient values

Coefficient of Soil Cover	X
Mixed and dense forest	0.05–0.20
Thin forest with grove	0.05–0.20
Coniferous forest with little grove, scarce bushes, bushy prairie	0.20–0.40
Damaged forest and bushes, pasture	0.40–0.60
Damaged pasture and cultivated land	0.60–0.80
Areas without vegetal cover	0.80–1.00
Coefficient of soil resistance	**Y**
Hard rock, erosion resistant	0.20-0.60
Rock with moderate erosion resistance	0.60-1.00
Weak rock, schistose, stabilized	1.00-1.30
Sediments, moraines, clay and other rock with little resistance	1.30-1.80
Fine sediments and soils without erosion resistance	1.80-2.00
Coefficient of type and extent of erosion	**ϕ**
Little erosion on watershed	0.10-0.20
Erosion in waterways on 20–50% of the catchment area	0.30-0.50
Erosion in rivers, gullies and alluvial deposits, karstic erosion	0.60-0.70
50–80% of catchment area affected by surface erosion and landslides	0.80-0.90
Whole watershed affected by erosion	0.90-1.00

Source: Gavrilovic, 1988

Table 2. Classification of Z coefficient values

Erosion Intensity	Category	Z value
Very low	I	<0.19
Low	II	0.20-0.40
Moderate	III	0.41-0.70
High	IV	0.71-1.00
Very High	V	>1.00

Source: Gavrilovic, 1988

According to the Z erosion coefficient, categorization of erosion processes according to Gavrilovic is given in the Table 2. Values usually range from 0.1 to 1.5 and above, respectively. from preserved, erosion of poorly affected plains and areas, to the plains which are extremely ruined due to soil erosion. These values can be above and below the limits only in exceptional cases (Gavrilović, 1988).).

RESULTS AND DISCUSSION

Erosion intensity map was done using GIS (ArcGIS 10.3.1) . Definition of the coefficients (X, Y, φ and Isr) was based on the spatial input data, namely DEM (Digital Elevation Model) (Figure 7) and satellite images of the area, land use/ land cover map (Figure 3), the geology(Figure 4) and the pedology of the area (Figure 5). The Y coefficient shows the soil resistance to erosion which is based on geology and soil data.

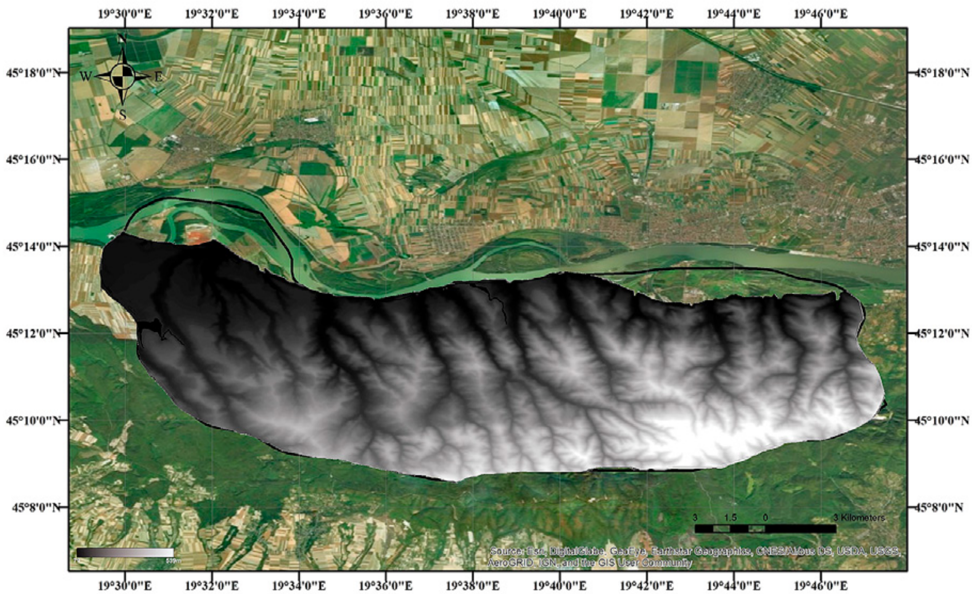

Figure 7. Digital Elevation Model (DEM)

Figure 7 shows Digital Elevation Model of Beočin, where the altitudes are given to the gray shades in the range of 0-255 pixels (from black to white), so that in the southern part of the image is the brightest shade (highest areas), and going north, east and west, where are smaller altitudes, shades become darker and approaching black. Figure 8 shows the reclassified digital elevation model in which 9 classes are separated in green and brown colours. Classes are formed to cover altitudes ranging from 79 m (the lowest hight on the DEM) to 539 m (the peak of Fruška Gora).

On the Figure 9 is shown the map of slopes with shaded relief where six classes of a slope are separated. The highest slopes are located in the central part of Fruška Gora. The greatest slope, obtained on the basis of the digital model of the terrain, does not exceed 27°.

After digitizing maps and assigning values to certain elements, a conversion to the raster format of a resolution of 30m was made where the attributes of X (Figure 10a) and Y(Figure 10b) were the conversion criteria in the raster base. The Raster database becomes adequate for using the calculation of the erosion coefficient Z according to formula (1). The result obtained is based on pixels where each pixel displays the value of the

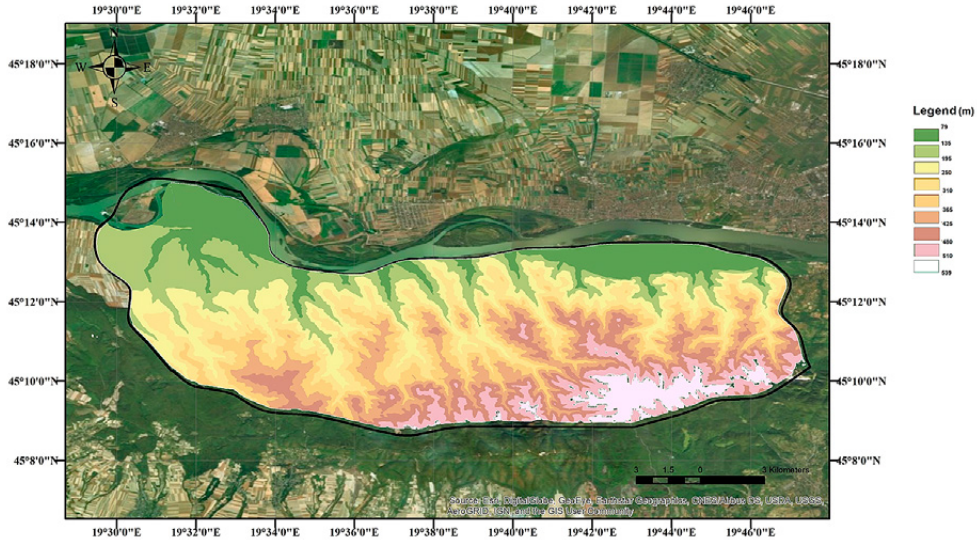

Figure 8. Classified DEM

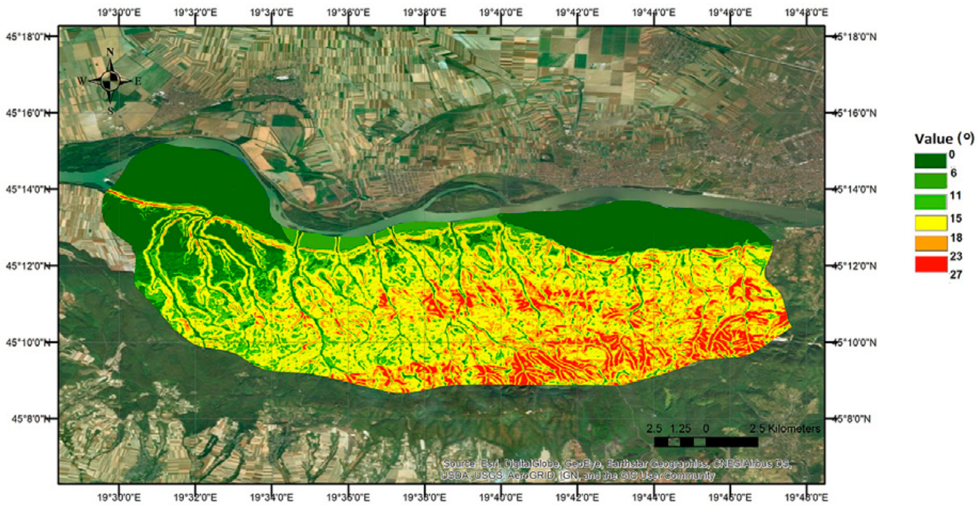

Figure 9. Map of slopes

Z erosion coefficient. By classifying the numerical value of the raster, a map of erosion is obtained (Figure 11). The erosion map shows the spatial distribution of erosion processes and provides an insight into the state of its intensity and character.

The surface erosion prevents, deep erosion occurs in the form of watercourses, furrows, rays on the slopes and in the waterways itself. The urvine processes and landslides are also present, as is the case with Čitlučki potok, Tekeniš and Čerević - Banoštor area (Fig.11).

Among the most significant factors influencing high values of the erosion coefficient is steep slopes and geologic composition that is prone to erosion.Slides are very pro-

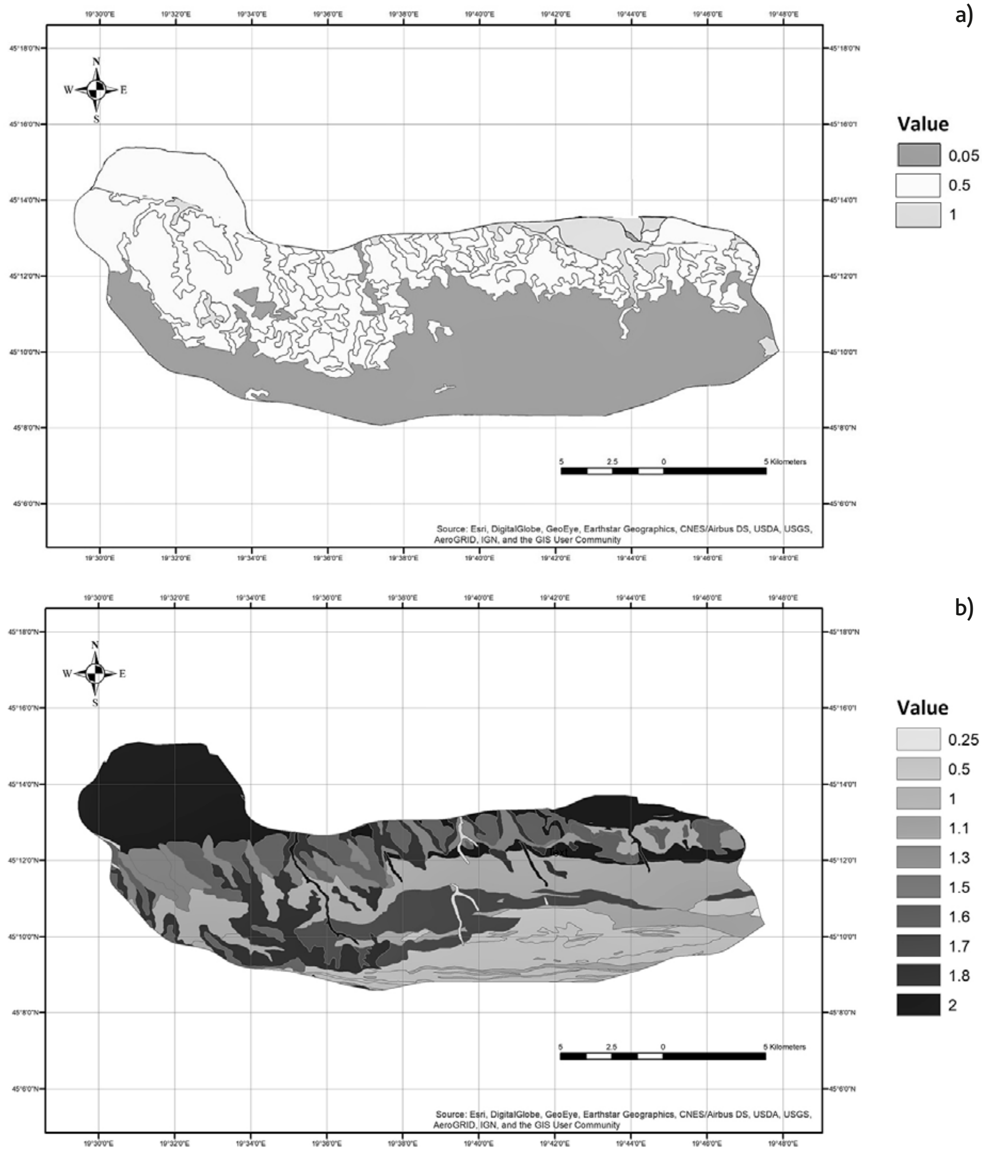

Figure 10. EPM coefficients: a) Soil protection coefficient (X); b)Soil erodibility coefficient (Y)

nounced on the right valley side of the Danube along the entire municipality. In the area of Fruška gora, the slipping process is particularly pronounced on certain sections, including ones from Neštin to Susek and from Banoštor to Čerević. The openings are present only on the edge of the loess plateaus. Particularly unfavourable is the destruction of loess on the contact areas of the landslides. The drainage is very present on the edges of loess deposits, in loess sediments, and also in the steep areas of the terrain, in almost all types of rock. Intensive dredging is particularly expressed in the central part of Fruška Gora.

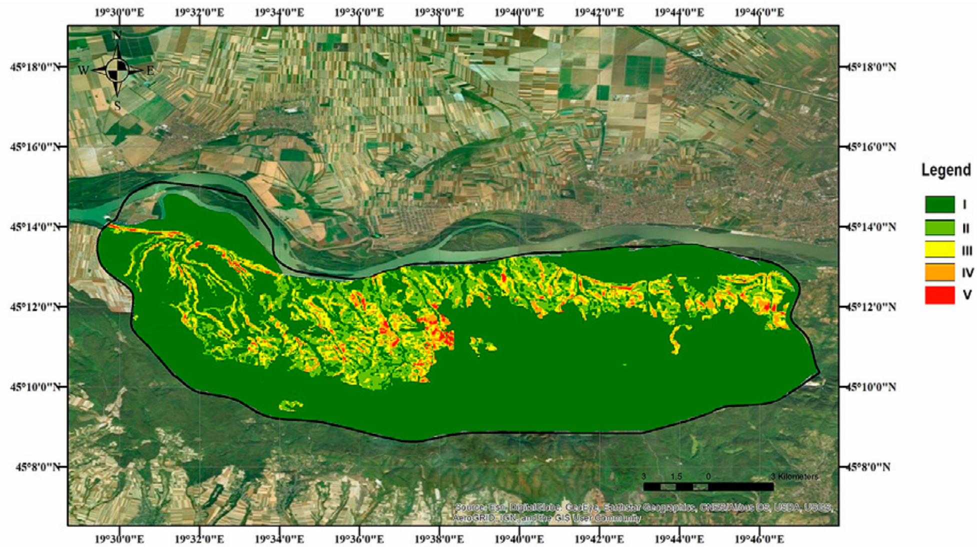

Figure 11. Erosion coefficient map (Z)

The intensified clinging of the thalweg is very pronounced, accompanied by the transport of large quantities of deposits into the foothills of the slope or into their mouth in the Danube. The flooding and large-scale decay of the soil appear on the right bank of the Danube in the area of alluvial plains.

The results of this article showed that EPM is an appropriate model to estimate soil erosion in Beočin municipality and this model can be suggested for some catchments which don't have sediment sampling stations or lack of databases needed for more complex models.

CONCLUSION

Soil, as a natural resource, represents a dynamic system created in the process of the pedogenesis, and under the influence of atmospheric and biological factors is constantly changing. With a view to assess the intensity of soil erosion and to propose measures for reducing the degradation process, developed many methods for assessing erosion loss of land. Erosion processes represent the basic factor of soil degradation, which leads to a number of negative changes in the physical and physical-chemical properties of the soil.

The erosion map prepared and calculated the erosion coefficient Z through this method is the basis for calculating the production of deposits in reservoirs and river basins. Processes ranging from the first to the fifth category of devastation were observed in the investigated area. The degree of threat to erosion processes is in proportion to the extent and type of activity in the catchment area, which was expected due to the large inclination of the terrain and unstable geological substrate. The surface erosion prevents, deep erosion occurs in the form of watercourses, furrows, rays on the slopes and in the waterways itself. The landslides are also present, as is the case with the Ležimirski brook, Novoselski brook and Čerević – Banoštor area.

The EPM proved to be suitable for defining erosion processes in the investigated area. The advantage of using this method is that it does not require a large number of input parameters and possible applications of GIS.

Further research should focus on creating a larger input database in order to apply some more advanced methods, such as the Revised Universal Soil Loss Equation (RUSLE) and the MMF (Morgan-Morgan-Finney). Also, further research should be related to the spatiotemporal parameter, which in this paper, because of the lack of data, was not possible.

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